7-1993

Inhibition, Distraction & the Aging Frontal Lobe

Robert West
Western Kentucky University

West,

Robert Lee

1993

INHIBITION, DISTRACTION, AND THE AGING FRONTAL LOBE

A Thesis

Presented to

the Faculty of the Department of Psychology

Western Kentucky University

Bowling Green, Kentucky

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Robert Lee West

July, 1993

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Date Recommended July 14, 1993

Karlene Ball
Director of Thesis

Daniel L. Roenker

Sharon Mutter

Date Approved July 28, 1993

Sara Evans
Dean of the College of Education and Behavioral Sciences

[signature]
Office of Graduate Studies

Acknowledgments

I would like to take this opportunity to thank the members of my thesis committee: Karlene Ball, Dan Roenker, and Sharon Mutter, for their invaluable support and suggestions throughout the completion of this project. I would especially like to thank Karlene Ball for the many opportunities afforded me during the past two years, and Dan Roenker, for assistance in data analysis and interpretation.

Table of Contents

List of Tables

List of Figures

INHIBITION, DISTRACTION, AND THE

AGING FRONTAL LOBE

Robert L. West July, 1993 59 pages

Directed by: K. Ball, D. Roenker, S. Mutter

Department of Psychology Western Kentucky University

Theories in both the fields of cognitive aging and human neuropsychology have suggested that an impairment in the ability of an individual to inhibit irrelevant or distracting information either present in the environment or generated within the individual can have detrimental effects on performance on a wide variety of cognitive tasks including text processing, inference formation, planning, and selective attention. A number of researchers have attributed this increased distractibility in both clinical populations and healthy older individuals to a decline in or impairment of the functioning of the frontal lobes. The present study extends findings suggesting a decline in frontal lobe function and increased susceptibility to distraction in healthy older individuals. In addition, the possible relationship between these two phenomena is explored in a systematic fashion, an analysis absent in previous literature.

Individuals ranging in age from 20 to 80 years completed a battery of tests designed to appraise frontal lobe function (WCST, FAS Word Fluency Test, Cognitive Estimation Test, and Stroop Color/Word Test) and to determine the effects of distractors on task performance (Useful Field of View, Negative Priming Task). To equate for general verbal intelligence and short term memory span, individuals also completed the Ammons Quick IQ Test and the Digit Span Forward subtest of the WAIS-R.

Consistent with previous research, older individuals generally showed a decline in frontal lobe function as well as increased susceptibility to distraction when compared to the young individuals. The decline in frontal lobe function can be seen by increased repetitions and elaborations on the FAS, increased perseverative errors on the WCST,

greater degrees of Stroop distraction, and a decreased number of categories being obtained on the WCST, with age. Increased susceptibility to distraction is suggested by the impairment of many older individuals on UFOV task 3 and the distraction measure of the negative priming task. There was also a decline in negative priming with increasing age for some older individuals. However contrary to past research, several of the older individuals demonstrated negative priming effects equal to those found in the younger subjects. The expected relationship between frontal lobe function and susceptibility to distraction was found to be significant. UFOV task 3 shared approximately 1/3 of its variance with the frontal lobe composite measure.

The present study extends previous work suggesting that one function of the frontal lobes is to modulate the effects of irrelevant or distracting information on efficient cognition. It also suggests that declines in inhibitory mechanisms, as assessed with the negative priming paradigm, can vary widely between older individuals.

Chapter I

Introduction

Over the past decade a number of studies have reported findings suggesting a decline in frontal lobe function with advancing age. Such findings have been reported with increasing consistency in the fields of neuropsychological testing and physiological psychology. In one study Ardila and Rosselli (1989) administered a battery of some twenty-nine neuropsychological measures to a group of subjects ranging in age from 55 to 76+, who were screened for evidence of neurological and psychological problems. Several tests in this battery were sensitive to frontal lobe function, including a verbal fluency task, WAIS Digit Symbol and Block Design subtests, and an abstraction task requiring concept formation. In all measures of frontal lobe function the effect of age was found to be significant. A study reported by Whelihan and Lesher (1985), designed to specifically consider frontal function, revealed similar findings. In this study six measures of frontal lobe function (WAIS Similarities subtest, modified Stroop Test, modified Hooper Visual Organization Test, Set Test, Sequential programming task, Finger Tapping) were administered as well as a number of non-frontal measures. The mental health of each subject was determined from scores on the Extended Mental Status Questionnaire (EMSQ), with a subject being considered healthy if he/she answered 90% of the questions correctly. Significant group differences were reported for all six frontal lobe measures between the healthy young-old, mean age 67.55, and the healthy old-old, mean age 79.88, groups, with the old-old performing below the young-old. In comparison only six of the eighteen non-frontal measures used revealed significant differences between these groups.

These findings led the researchers to suggest that the efficient functioning of the frontal lobes may be more susceptible to the effects of normal aging than the posterior lobes (Whelihan and Lesher, 1985). Unfortunately no higher order analyses were conducted in this study to examine the possibility of some common underlying mechanism operating within the frontal lobe tasks.

Studies measuring regional cerebral blood flow (rCBF) have also reported decline in frontal lobe function with advancing age. Shaw et al. (1984), using a cross-sequential method, reported a correlation of ($r = -.34$) between age and rCBF. Shaw et al. (1984) further report significant declines with age in rCBF for the prefrontal, parietal, inferior temporal, and fronto-temporal regions, with the prefrontal area demonstrating the greatest loss, a (-27%) reduction in blood flow across the age groups. This finding is supported by the work of Melanmed, Sylvan, Bentin, Cooper, and Rinot (1984) who found a correlation of ($r = -.46$) between age and rCBF in a sample of adults ranging in age from 19 to 79 years, screened for evidence of central nervous system pathology, dementia, hypertension, and pulmonary abnormalities. These findings were replicated in a study which found significant declines in rCBF for the two detectors monitoring the frontal lobes in both hemispheres for an old group (ages 49-67), when compared to a young group (age 20-28)(Warren, Butler, Katholi, and Halsey, 1985). These findings led Warren et al. (1985) to suggest a "reduction in the pattern of hyperfrontality" normally seen in rCBF studies, resulting in the cortex of the older individual being "chronically underaroused" (p. 58). These findings suggest that part of frontal lobe deficits commonly observed in many older individuals may be related to functional changes within this region of the cortex.

The importance of intact inhibitory mechanisms for efficient performance of cognitive tasks has been suggested by researchers in a number of fields within psychology. Dempster (1991) contends that intelligence cannot be fully understood without a

consideration of the role of inhibitory processes, and suggests that the inhibitory ability of the individual is a direct measure of the efficiency with which the frontal lobe is functioning. The notion that inhibitory mechanisms are located within the frontal lobe is supported by a number of neuropsychological studies revealing that patients with frontal lobe lesions often perform poorly on tasks requiring active inhibition of one type or another. For example, Milner (1964) found that patients with frontal lobe lesions performed poorly on both the WCST and a measure of verbal fluency; both of which are considered to involve the use of inhibitory mechanisms. Likewise, Perret (1974) and Golden (1976) report poor performance on the Stroop Color-Word Task by patients with lesions to the frontal cortex. Understanding the relationship between frontal lobe function and inhibitory processes certainly seems important given recent theoretical speculation related to the role that such processes play in adult cognition.

The working memory model of Hasher and Zacks (1988) contends that many of the memory problems experienced by older adults result from a breakdown in the efficient functioning of inhibitory mechanisms. Research involving the negative priming paradigm has typically been used to support this position. In the negative priming experiment, the subject is presented with a pair of stimuli (stimuli have included letters, line drawings, and dots), one of which serves as the target and the other which is to-be-ignored . On the following trial, the to-be-ignored stimulus becomes the target. Negative priming occurs when reaction time to the target is slowed as a result of suppression from the previous trial. Responses have taken the form of letter naming, word reading, and spatial localization. Studies using this paradigm typically reveal negative priming effects in younger, but not older subjects (McDowd & Oseas-Kreger 1991; Hasher, Stoltzus, Zacks, & Rypma, 1991), suggesting that older adults are failing to inhibit the to-be-ignored stimuli. Studies using the Stroop Color-Word Task have also reported increasing interference scores with increasing age (Comalli, 1962).

The purpose of the present study is to extend the findings pointing to a decline in frontal lobe function with age and to explore the notion that this decline is related to a decline in inhibitory function often observed in older individuals. This seems a worthwhile undertaking given the comments of researchers like Milner (1964) and Perret (1974) who suggest that the "frontal lobe patient seems unable to suppress his ongoing responses" (p. 331) and that the frontal lobe patient suffers from an inability to "suppress the normal habit" (p. 329) when required to effectively perform the task, a well as recent findings indicating a decline in inhibitory mechanism efficiency with increasing age.

To further explore this notion of decline in frontal lobe function as a result of the normal aging process, a set of four measures, previously demonstrated to be sensitive to frontal lobe function, were administered to three groups: a group of college undergraduates (age 20 to 31), and two groups of older individuals, a young-old (ages 60-69) and an old-old group (ages 70-80). Albert and Kaplin (1980) have suggested that a good "frontal-system battery" should include measures of fluency, inhibition, and abstraction or conceptual ability. While there are many tasks that have previously been used as measures of these abilities, the present study will be limited, with the exception of the Cognitive Estimation Task (CET), to measures which have demonstrated sensitivity to frontal lobe function in both studies of the normal elderly population and various brain pathology populations. The Wisconsin Card Sorting Task (WCST) was used as the measure of abstracting ability. The selection of the WCST seems logical for a number of reasons: 1) it exists in a standardized form with available norms, 2) a number of interesting measures can be derived from the results of the test, and 3) the sensitivity of the test to frontal dysfunction has been demonstrated with a variety of clinical populations (Nelson, 1976; Stuss et al. 1983; Robinson, Heaton, Lehman, & Stilson, 1980). The measure of fluency used was the FAS Word Fluency Task (FAS). While not standardized like the WCST, the FAS has been used with several different clinical populations as well as in

studies using normal elderly subjects (Miller, 1984; Perlmuter et al., 1987). A second reason for using the FAS lies in the method of response collection. Unlike several word fluency tasks, the responses of the subject on the FAS are recorded by the experimenter, not written down by the subject. This method of recording responses is preferable in that it eliminates some of the disadvantages the older person may suffer due to slower writing speed, a common result of motor function decline.

The Stroop Color/Word test was used as one measure of inhibition/distraction. The selection of this measure is well justified given the ease with which it can be given and scored as well as the robustness of the effect that has consistently appeared through countless variations of the basic task. The version of the Stroop to be used for this study is described below. Like the WCST and the FAS the Stroop Color/Word has been linked to frontal lobe function and the effects of aging on numerous occasions (Cohn, Dustman, & Bradford, 1984; Comalli, Wapner, & Werner, 1962; Perret, 1974).

The Cognitive Estimation Task (CET) served as the final measure of frontal lobe function. This task is considered to be a measure of "planning" and the "use of knowledge in unconventional ways" (Shallice, 1978, p. 301). The number of studies reporting on the CET is somewhat limited. However, a reliable sensitivity to frontal lobe pathology does appear to exist (Leng & Parkin, 1988; Shallice, 1978; Shoqeirat et al. 1990). Unlike the three other frontal tasks, the CET has not been previously employed in studies of aging. There are, however, some correlational data suggesting a decline in estimation ability with age in clinical populations (Shoqeirat et al., 1990). Therefore, one of the goals of the present study will be to explore more extensively the effects of age on estimation ability in a healthy sample of individuals.

The Ammons Quick IQ Test and the Digit Span Forward subtest of the WAIS-R were included as demographic variables. The QT was used as a measure of general verbal intelligence, which can be administered and scored quickly and is insensitive to the effects

of age. Cohn and Dustman (1984) have reported a correlation of only (r = .04) between QT scores and age, suggesting that age will have a minimal effect, if any, on the QT. Studies examining the relationship between the QT and WAIS full scale scores have reported correlations ranging from (r = .64) to (r = .91), suggesting that the QT is a valid measure of general verbal intelligence when compared to more extensive measures of intelligence (Traub & Spruill, 1982; Ciula & Cody, 1978). Digit Span Forward was included for its insensitivity to the effects of age and as a measure of short term memory.

The visual attention of each subject was also measured using a UFOV Visual Attention Analyzer. The UFOV task was included to provide a nonverbal measure of distractability. Past research has suggested that the visual localization ability of some older individuals is significantly impaired when a target is embedded in a field of distractors (Sekuler & Ball, 1986).

A negative priming task similar to that reported by McDowd and Oseas-Kreger (1991) was also included to provide another measure of the effects of distracting information and a measure of active inhibition. The inclusion of the negative priming paradigm seem important for a number of reasons. The paradigm provides both a measure of inhibition and distraction within the same task. The findings of small yet reliable inhibition effects have been reported in several studies using young subjects (Tipper, 1985; Tipper & Baylis, 1987). In addition, findings using negative priming tasks have been used to support the Hasher and Zacks (1988) theoretical framework suggesting declining inhibitory mechanisms in older individuals (Tipper, 1991).

A number of hypotheses will be addressed in the hope of gaining a better understanding of the relationship between declining frontal lobe function and changes in

inhibitory function and distractibility across the adult life span.

1. There will be a decline in frontal lobe function with increasing age, demonstrated by the decline in scores across age groups for the four frontal lobe measures.

2. Poor performance on the CET, WCST, Stroop Color/Word, and FAS is related to a decline in inhibitory control and an increase in distractability often associated with age.

3. Older subjects with high degrees of inhibitory function loss will perform worse on the measures of frontal function than older subjects with no or minimal inhibitory difficulties.

4. There will be an increase in distractability with increasing age, demonstrated by increasing Stroop interference, negative priming distraction, and UFOV task 3 scores across the three groups with increasing age.

5. The decline in inhibitory function will not be universal with age(i.e., not all older subjects will experience equal rates of decline).

Chapter II

Review of the Literature

To more firmly establish the notion of a decline in frontal lobe function with increasing age, the following pages will contain findings from research involving each of the four measures of frontal lobe function. The findings surrounding each of the tasks will be reviewed independently for the most part. This seems to be a reasonable approach considering that few studies have examined the possible relationships between these tasks directly. Fortunately there have been a few studies that have examined the relationships between the frontal lobe measures, and these will be considered along with some of the theoretical explanations suggested to explain these relationships. A discussion of Hasher and Zacks (1988) theory of inhibitory decline will follow, including relevant research findings.

Verbal Fluency

Tests of verbal fluency typically ask the subject to produce as many words belonging to a given category as possible in a given amount of time. Responses can be either written by the subject or provided orally and recorded by the experimenter. Test stimuli have ranged from single letters to categories such as animals or items found in a grocery store (Kolb & Whishaw, 1983; Rosen, 1980; Whelihan & Lesher, 1985). Performance deficits have been found in clinical populations with lesions of the left and right frontal region as well as in healthy elderly samples.

The sensitivity of tests of verbal fluency to frontal lobe damage has been demonstrated in groups with a number of different etiologies. Miller (1984) compared the performance of patients with focal lesions of the frontal and posterior regions to the scores

of demented and normal controls on the FAS Word Fluency Test. The analysis revealed that both the left and right frontal lobe groups as well as the demented group scored below the controls and that there was no difference among these three groups. Miller (1984) also reports the lack of a significant relationship between age and fluency, ($r = .09$) in his control group (mean age 50.6 and standard deviation 10.4), which is interesting in the light of other findings to be presented in the following paragraphs. Similar findings have been reported in studies that included only patients with unilateral lesions resulting from surgery. Milner (1964) reports that patients with left frontal lesions were impaired on her task of fluency when compared to patients with lesions of the right frontal and left temporal lobes. Similar findings are recounted by Perret (1974); in that study both the left and right frontal groups performed poorly when compared to groups with temporal and posterior lobe lesions as well as controls. An effect of hemisphere was also found with the left hemisphere groups performing more poorly than the right hemisphere group and the left frontal group performing the poorest of any group. A study using Korsakoffs and Post-encephalitic amnesiacs has also suggested a frontal deficit for word fluency, as evidenced by both amnesiac groups performing below the level of normal controls (Shoqeirat et al., 1990).

Studies exploring the effects of normal aging also have demonstrated consistent declines in verbal fluency scores with increasing age. In studies designed to examine the effects of age on a broad range of neuropsychological instruments, declines in fluency have been reported (Whelihan & Lesher, 1985; Ardila & Rosselli, 1989). Ardila and Rosselli (1989) report significant age differences on both semantic and phonological verbal fluency tests. These tests involved naming either semantically related objects (i.e., fruits and animals) or phonologically related words (i.e., beginning with the letters *S* and *A)*. A verbal fluency task similar to the semantic test mentioned above required the subject to name items which could be purchased in a supermarket. Again a significant difference in

fluency was found to exist between a young-old group and an old-old group. The work of Schaie and Strother (1968) has demonstrated a reliable decline in verbal fluency ability with age in both longitudinal and cross-sectional data, with declines in fluency beginning as early as age 25 in the cross-sectional data and greater declines being suggested within rather than between cohorts.

In a study designed to examine changes in verbal fluency resulting from age and diabetes, the number of words generated did not differ from the normal young to the old groups (Perlmuter, Tun, Sizer, McGlinchey, & Nathan, 1987). However, when the number of "repetitions," repeating a word that was previously given, and "elaborations," providing an alternate form of an earlier given word, were compared for the two groups significant effects of age were found. From these results, the researchers suggested that the decline in verbal fluency does not result from a loss of general verbal ability, but rather from a failure to monitor responses, demonstrated by the repetition and elaboration of words both of which were against pre-established rules.

Declines in verbal fluency are reliably demonstrated in both patients with frontal damage and as a result of advancing age. This deficit does not appear to be an artifact of any one particular type of stimulus in that the deficit persists when the task requires either semantic or phonological category organization. Also, declines in verbal ability would not appear to be the result of loss of vocabulary skills with age. Perlmuter et al. (1987) report that in their study the older controls actually out performed all other groups on the WAIS vocabulary subtest. The decline in verbal fluency would appear, on the other hand, to result from a breakdown in the ability of the individual to monitor and control responses.

Concept Formation and the WCST

Tests of concept formation, such as the Wisconsin Card Sorting Task (WCST), typically require subjects to sort a series of cards according to a consistent category. The goal of the subject is to discover the underlying concept and to consistently sort the cards

using the discovered rule. The WCST requires the subject to sort a series of 64 cards according to either color, form, or number. As each sort is made the examiner remarks correct or incorrect, thereby providing feedback as to response accuracy. If, for example, the sorting category was color the subject would be expected to sort all the red cards into one pile, all the green cards into another pile and so forth. After ten correct sorts have been made the concept is changed by the examiner, unknown to the subject, and the subject must now discover the new concept by continuing to sort the cards. The task is discontinued after six categories have been attained or the 128 cards have been exhausted. A number of measures can be derived from the test; however, the most useful are the number of categories attained and the number of perseverative errors made. Perseverative errors result when a subject continues to sort to a category that is no longer correct or continues to sort to a category initially incorrect. Testing with the WCST and similar concept formation tasks have revealed reliable declines of performances in both clinical populations with frontal lobe damage and in normal elderly.

The sensitivity of the WCST to frontal lobe pathology has been revealed in a number of studies using clinical populations ranging from Korsakoffs amnesiacs to individuals who have undergone surgical lesioning of the frontal lobes. The work of Milner (1964) is perhaps the most often cited in this area of study. In that study a group of patients with dorsolateral frontal lesions made more perseverative errors and achieved fewer categories when compared to groups with inferior frontal, bilateral hippocampal, and posterior cortex lesions. Similar results were reported in a study comparing Korsakoffs and Post-encephalitic amnesiac patients with normal control, matched for age and IQ (Shoqeirat et al., 1990). Korsakoffs patients were found to be inferior to all other groups on both Heaton's and Nelson's versions of the WCST. Other interesting findings are reported by Stuss et al. (1983). In the first 64 card deck of the WCST no differences were reported among the three frontal leucotomy groups and the controls. However, on

the second 64 card deck the controls achieved significantly more sorting criteria than any of the frontal groups. This difference was attributed to an increase in the number of correct sorts made by the control group while the three frontal groups continued with a sorting accuracy almost equal to that of the initial 64 cards (Stuss et al., 1983).

Declines in concept formation ability have also been reported as a result of the aging process in a number of studies. In a study examining the relation of source amnesia to frontal lobe function, Craik, Morris, Morris, and Loewen (1990) reported a significant correlation of (r = .53) between age and WCST perseverative errors in a sample of older subjects' age 60-84. Commenting on this finding and those of Heaton (1981), Craik et al.(1990) suggest that "the most striking difference between the young and older subjects is the increase in perseverative errors by the older subjects"(p. 150). Two other studies (Hess and Slaughter, 1986; Flicker, Ferris, Crook, and Bartus, 1986) have also reported declines in concept formation ability with advancing age. Using a sorting task similar to the WCST, Hess and Slaughter (1986) found that only 52% of their older subjects, compared to 96% of their younger subjects, were able to state the proper concept rule within the allotted trials. In similar manner, Flicker et al. (1986) report that their healthy older group was outperformed by their younger group on a task of concept formation.

Using a modified version of the WCST, designed to be less frustrating than the traditional test, Nelson (1976) found correlations ranging from (r = -.57) to (r = -.79) between age and number of categories obtained for his patients with non-frontal damage and his controls. However, the correlations between age and percent perseverative errors did not reach significance. This second finding may have resulted from the modifications in the test, because the individual was informed of the occurrence of a category shift. In the discussion of the findings, success on the sorting task was said to be attributable to two components. First, the individual must be able to "form concepts based upon information concerning class membership" and second the individual must be able to

"inhibit one mode of response in favor of another when this becomes appropriate" (Nelson, 1976, p. 322).

Cognitive Estimation

The Cognitive Estimation Task (CET) introduced by Shallice (1978) consists of a series of fifteen questions that require the individual to estimate the size, number , or amount of various objects. While the individual may not know the exact answer to the question, s/he is encouraged to make the best guess possible. For example consider the question. What is the age of the oldest living person in the United States? While most people probably do not know the answer to this question outright, a reasonable estimation of the figure could be expected. Studies reporting on the CET are somewhat limited, however available findings suggest that the CET is sensitive to frontal lobe dysfunction.

Shallice (1978) found significant group differences in test performance when comparing patients with either anterior or posterior lesions, suggesting a "frontal defect." He also suggests that difficulty on the CET cannot be attributed to declines in general intelligence or arithmetic ability as group differences remain when each is controlled as a covariant. When age was included as a covariant of CET performance however, group differences reached significance in only two of fifteen ANCOVA procedures conducted. One possible explanation for this finding, given evidence to be presented later, is the relatively strict criteria with which the results were scored. The findings of Shallice (1978) were supported by a study that found a group of Post-encephalitic amnesiacs to be impaired on the CET (Leng & Parkin, 1988). In a follow-up to the Leng and Parkin study, Shoqeirat et al. (1990) explored the relationship of CET performance to WCST and FAS performance, as well as WAIS IQ scores. The relation between CET performance and age was also considered. Again an effect of site of lesion, anterior/posterior, was revealed as demonstrated by the poor performance of both Post-encephalitic and Korsakoffs amnesiac groups, thus supporting the results of the two studies mentioned

above. A correlation of ($r = -.34$, $p < .10$) between CET and FAS approached but did not reach significance. CET performance was found to correlate with age and all of the WAIS measures (i.e., Full, Performance, and Verbal IQ scales). The relation of the CET to WAIS performance might be predicted by Shallice since his measure of general intelligence was a reliable covariant. On the other hand, the relation of age and the CET would not be anticipated by the work of Shallice (1978) since age was a reliable covariant in only two of the analyses in which it was included.

Seeking to extend the findings of Shallice, Smith and Milner (1984) developed an estimation task that required the subject to estimate the price of a real world object when presented with a toy example of the object. Here again the subjects were encouraged to make the best guess possible. For instance, the subject might be shown a toy bicycle and asked to estimate the price of a full size one. The researchers found that patients with right frontal lobe lesions made more errors than the right and left temporal lesion groups, as well as the control group. In addition, Smith and Milner (1984) suggest that CET impairment cannot be accounted for by inattentiveness of the right frontal lobe patients to the task since this group performed equal to or better than the other groups on a test of spatial memory given after the estimation task.

From the research presented above the CET would appear to have a strong relationship to general intelligence as demonstrated by its correlation with each of the WAIS measures. However, the task also appears to tap some unique element of cognitive functioning. Shallice (1978) has suggested that impairment on the CET is possibly linked to a breakdown in the ability of selection and regulation of an appropriate plan for arriving at a reasonable estimation for the question at hand.

Stroop Color-Word Test

The Stroop Color-Word Test, first published in 1935, has become one of the most robust measures of interference in psychology. The Stroop typically consist of three

cards, a "color" card, a "word" card, and a "color/word" card. The color card is made up of a series of colored patches. The subject is required to name the color of each patch as quickly as possible. The word card contains the names of the colors represented on the color card. Here the subject is to read the names of the colors as quickly as possible. The color/word card consists of the names of colors printed in a color other than that named. The subject is required to name the color of the stimulus while disregarding the word itself. The measure of interest is most often the difference between naming times for the color and the color/word cards which is taken to be a measure of interference. This effect has endured across a seemingly endless number of task modifications and subject populations. Here the effects of brain damage and normal aging will be considered on Stroop performance.

Findings of the effects of brain damage on Stroop performance have been somewhat mixed. Perret (1974) found that patients with left hemisphere lesions were impaired on the color/word part of the task when compared with patients with right hemisphere lesions and controls. Moreover, the left frontal group performed the poorest of any group. These findings led to the suggestion that there are two factors operating in the deficit of the left frontal group. The first is an "inability to handle verbal information correctly," left hemisphere, and the second an "inability to separate two categories within a single stimulus, in order to suppress one, a frontal defect" (Perret, 1974, p. 329). A second study compared the performance of normals, schizophrenics, and patients with either left, right, of diffuse brain damage (Golden, 1976). Significant main effects were revealed for color naming, word naming, and the color/word measures of the Stroop test, with the controls performing better than all other groups. Inspection of the reported means reveals that the left brain damaged group had the lowest scores on all measures; however, this difference reached significance only between the left brain damaged and the schizophrenic and control groups. A discriminant analysis was reported with correct

group classification rates ranging from 74.2% for the right brain damaged group to 94.6% accuracy for the controls. Results were not as optimistic when a second function seeking to predict laterality was applied, suggesting accuracy rates of only 56.7%. Golden (1976) further describes findings from five of his subjects considered similar to Perret's left frontal group. These five subjects scored within the normal range on the color naming and word reading sections of the task but performed very poorly on the color/word card. The results of Golden (1976) while not completely consistent with those of Perret (1974) do suggest a deficit in Stroop performance resulting from frontal lobe damage.

Research examining the effects of aging on Stroop performance has also provided a number of interesting findings. In a study employing subjects ranging in age from 7 through 80 years, Comalli et al. (1962) found a U-shaped function for performance on the color-word card of the Stroop, where naming time steadily declined until age 17, stabilized through age 44, and began to increase from there. Color naming and word reading also declined with age until age 17 and then stabilized throughout adulthood. A second study examining the effects of aging on Stroop performance revealed similar findings (Cohn et al. 1984). There were no differences between age groups on the word and word/color, for this part of the task the color/word card is used and the subject is asked to read the words, trials of the test. However, the older group was slower than younger group on both the color naming and color/word trials of the test. A reliable difference was also reported between the color naming and color/word task revealing a significant effect of interference. In post-hoc comparisons, the 60-90 year old group was found to beinferior to the younger two groups on the color/word task, suggesting a greater effect of interference for the older subjects. Correlations between age and color naming of ($r = .72$) and age and color/word naming of ($r = .63$) were also reported further suggesting a relationship between Stroop-type interference and aging.

The findings reported above suggest that there is a reliable decline in Stroop Color/Word Test performance with increasing age as demonstrated by the greatest degree of impairment being demonstrated for the color/word sections of the task. This decline appears to reside in the inability of the older individual to moderate between competing aspects of a stimulus. Studies using clinical populations have provided somewhat mixed results; however the Stroop Color/Word Test does appear to be a good predictor for the presence of brain damage, with some evidence suggesting sensitivity to a frontal lobe defect.

The Nature of the Frontal Lobe Defect

To this point the findings from the four tests sensitive to frontal lobe damage and the effects of normal aging have been considered somewhat independently. At this time the question emerges: What do these seemingly very different task have in common? What common element do tests of concept formation, verbal fluency, cognitive estimation, and interference share? While no single study has explored this question in a systematic way, by weaving together a number of findings and suggestions from various writers, a common theme does begin to emerge. In his study, Perret (1974) reported correlations between verbal fluency and the Stroop Color/Word task ranging from (r =-.46) to (r =-.72), for his various patient groups. In discussing these findings Perret suggested that the "common denominator" between the Stroop and verbal fluency test is the ability of the individual to suppress the "normal habit" in order to provide the appropriate response. Shoqeirat et al. (1990) reported a correlation of (r =-.34), which almost reached significance, between scores of the FAS and the CET. Correlations of (r =.25) and (r =-.25) were also reported between the WCST and the FAS and CET respectively. However, no explanation of these findings was provided. Reporting on findings involving a modified version of the WCST, Nelson (1976) suggested that difficulty on the task results when the individual is unable to inhibit "one mode of response in favor of another

when this becomes appropriate"(p. 322). Likewise, Milner (1964) discussing findings on both the WCST and a verbal fluency task suggested that the "frontal lobe patient seems unable to suppress his ongoing responses" and further that the "frontal lobe deficit manifests itself as an inability to overcome a previously established response set"(p. 331). From these findings and from those reviewed earlier, the existence of an underlying inhibitory mechanism is hypothesized which somehow affects each of these tasks.

A decline in the efficient functioning of this inhibitory mechanism is revealed in the inability of the older individual to suppress irrelevant or extraneous information. In verbal fluency tasks this breakdown can be seen in the repetition of previously reported words and the introduction of words in violation of the task rules. This deficit manifests itself in the WCST in the form of perseverative errors or the inability to suppress previous responses when no longer appropriate. In the CET this deficit could result in the inability of the individual to mediate between possible answers in order to arrive at a logical estimation. Problems on the Stroop Color/Word Test arise from the inability to suppress highly over learned verbal material in order to respond to color. In short the poor performance on each of these tasks relates to the decline in the efficient functioning of inhibitory mechanisms. In order to more fully explore this notion of inhibitory decline the theoretical framework of Hasher and Zacks (1988) will be considered in some detail.

The Inhibition/Distraction Hypothesis

In 1988, Hasher and Zacks published a theory of working memory which suggested that many of the memory deficits observed in older adults can be ascribed to the breakdown of "inhibitory mechanisms" with age. The theory suggests that as these inhibitory mechanisms decline in efficiency, "off goal path" information is allowed to find its way into working memory. This irrelevant information can exist in one or all of three forms; 1) irrelevant contextual and/or environmental details; 2) personalistic memories or concerns, and 3) off goal path interpretations. The entrance and prolonged maintenance

of irrelevant information in memory could result in a number of problems. Hasher and Zacks (1988) suggest two; part of the goal-path message could go unprocessed or the individual could suffer a reduction in the ability to shift attention from one target to another, leading to problems in selective attention. The authors further suggest that the reduction of inhibitory control might be accentuated when rapid processing or responses to a stimulus are warranted.

Research investigating this theoretical framework has only begun to be reported; however, studies employing the negative priming, visual search, and environmental support paradigms have provided findings consistent with the theory. As described earlier in the negative priming paradigm two stimuli are presented simultaneously--one stimulus serves as the target, the other is to-be-ignored. In this type of task the subject is asked to name the target stimulus as quickly as possible. On the following trial the to-be-ignored stimulus from the previous trial becomes the target. Negative priming is observed when reaction time to the target is slowed as a result of suppression from the previous trial. McDowd and Oseas-Kreger (1991) using a negative priming task found that their older subjects failed to demonstrate negative priming for letters, while their younger subjects did. A further analysis divided the young and old subjects into fast and slow groups according to reading speed, suggesting that the slower older subjects were perhaps off setting a small priming effect in the fast older subjects. This analysis revealed that neither of the older groups demonstrated negative priming, while both the fast and slow younger groups did, leading the researchers to conclude that the decline of inhibitory mechanisms proceeds somewhat independently of age related slowing (McDowd & Oseas-Kreger, 1991). A second study using the negative priming paradigm reported findings very similar to those mentioned above (Hasher et al. 1991). In experiment 1 of this study, subjects were to name a target letter as quickly as possible and to ignore a distractor letter appearing in a different color when they appeared on the screen. Trials could be either

sequential (target same as previous distractor) or control (no relation between targets and distractors) with greater reaction times being expected on the sequential trials if negative priming occurred. As expected young subjects naming times were reliably slower on the sequential trials and older subjects reading times did not differ reliably between the two conditions with an Response-to-stimulus onset interval (RSI) of 500 msec. Experiment 2 explored the hypothesis that older subjects might demonstrate negative priming if given a longer RSI, suggesting that in the first experiment inhibition might not have had time to develop in the older subjects. To test this hypothesis an RSI of 1200 msec was used with the same stimuli as experiment 1. Again older subjects failed to demonstrate negative priming. From these findings the researchers suggest that the failure of their older subjects to demonstrate negative priming resulted from an actual deficit in some inhibitory mechanism and was not simply an artifact of declines in processing speed of the older subjects. Tipper (1991) reports similar findings in a study using an 1100 msec RSI. In this study young subjects showed a 15 msec suppression effects and old subjects demonstrated a facilitory effect of 26 msec, again evidence of declining inhibitory function with age.

Measures of distractability often included in negative priming task also provide evidence of declining inhibitory mechanisms with age. In the McDowd and Oseas-Kreger (1991) study a measure of distractability was obtained by comparing subjects reading times for letter strips containing either single letters or pairs of letters slightly overlapping. Both young and old subjects reading times were slowed by the addition of distractors, with older subjects being much more impaired than young [mean effect size for young (.92 seconds) and old (2.29)]. Tipper (1991), using either pictures (distractor) or scrambled lines (control), reports similar findings with old subjects naming times (42 msec) being much more impaired by the presence of a distractor than young subjects (8 msec).

Research in the area of visual search has also provided evidence of increased distractability with age. In a study by Sekuler and Ball (1986) subjects were required to localize a peripheral target presented on a 30 X 30 degree visual display. Trials consisted of one of 4 types (localization alone, distractor added, central task added, and distractor + central task added). The central task required the subject to identify which of two expressions (smile or frown) appeared on a cartoon face presented in the center of the display. The distractors consisted of outline boxes the same size and luminance as the peripheral test face. Analysis revealed that the addition of the central task impacted both young and old groups equally, increasing error rates in both groups. In comparison the addition of distractors to the display had a much more profound effect on the error rates of older subjects, especially with increasing eccentricities. In a second study subjects were again required to localize a peripheral target with varying degrees of distraction and central task difficulty (Ball, Beard, Roenker, Miller, & Griggs, 1988). The central task could require the subject to make a present/absent judgment, the smile/frown decision as in the previous study, or a same/different judgment for two faces presented in the center of the display. The display also contained one of three levels of distractors (0, 23, or 47). Again old subjects' localization performance was more impaired by the addition of distractors than young or middle-aged subjects. This research suggests that increases in distractability are not limited to tasks requiring either verbal or speeded motor responses.

Further support for the Hasher and Zacks (1988) theory is found in a study that varied the amount of environmental support for reading passages. In the environmental support paradigm the salience of a cue is varied in an effort to improve task performance. In the present study Shaw, Rypma, and Toffle (1992) varied the contrast between target and distractor words within a reading passage. They discovered that older adults became significantly slower with each increase in distractor difficulty, while the younger subjects were impaired only in the most difficult of conditions. The researchers also report an

experiment examining whether or not the distractors had been processed using a lexical decision task. They found that older subjects demonstrated priming for the distractor words while younger subjects did not. This finding suggests that a breakdown in the inhibitory process can have a "long-term effect" on memory.

Given the above findings, there does appear to be a degree of validity to the theoretical framework proposed by Hasher and Zacks (1988). A decline in the efficient functioning of some inhibitory mechanisms does appear to occur with increasing age. In their closing statement McDowd and Oseas-Kreger (1991) suggest that further research should explore the "generality of this phenomena" to other "task and paradigms." The present study represents an attempt to do just that by examining the relationship of the four frontal lobe function measures to age related declines of inhibitory control.

Chapter III
Method

Subjects

Twenty volunteers were recruited from each of three age groups. One group was made up of college students recruited from either an introductory statistics class or the campus population. The other two groups were recruited from the community and consisted of older adults. The young-old group was made up of ages (60-69) and the old-old group ages (70-80). All subjects received payment of $10.00 per hour for their participation. Subjects were screened through self-report for occurrence of stroke, head injury, neurological disease, high blood pressure, diabetes, heart disease, psychological problems, and drug use. In addition all subjects were screened for color vision defects and visual acuity.

Materials

In the FAS Verbal Fluency Task, subjects were required to say as many words as possible beginning with the letters *F*, *A*, and *S*, in separate one minute trials. Subjects were instructed not to use proper names of people or places, not to repeat a word or to use an alternate form of a word (e.g., do and doing). Rule violations are corrected once during each trial if necessary, and the order of the letters was consistent across subjects. Responses were recorded on audio tape for scoring purposes . The subject was scored on the total number of words given across the three trials minus the total number of repetitions and elaborations. In addition, the total number of repetitions and elaborations, defined as occasions when a subject repeated or used an alternate form of a word, was used as a measure of perseverance.

A computerized version of the Stroop Color/Word Test was used. This task consisted of three screens each containing two columns of eight stimuli for a total of sixteen stimuli on each screen. The "Color" screen consisted of colored rectangles with each of four different colors being presented four times. On this screen the subject was asked to name the color of each rectangle as quickly as possible without making errors and to correct any errors made. The "Word" screen consisted of four color names presented four times each; on this screen subjects were instructed to read the names of the colors as quickly as possible without making errors and to correct any errors made. The "Color/Word" screen consisted of the four color names each presented four times in an opposing color, with the four color inks appearing an equal number of times. On the "Color/Word" screen, subjects were instructed to name as quickly as possible the color in which the word appeared and to ignore the color name without making errors and to correct any errors made. Subjects' response time and errors were recorded for each screen. Responses were audio tape recorded for later confirmation of errors. For the Stroop Color/Word Test a measure of interference was calculated by subtracting the naming time to the Color screen from the naming time to the Color/Word screen.

The negative priming task (modeled after that reported by McDowd & Oseas-Kreger, 1991) consisted of 18 screens, containing two columns of thirteen letters or letter pairs. Lists were 13 cm in height and 7.5 cm separated the inside letter positions, all letters appeared in uppercase form and were 1 cm in height. The same six letters (A,C,E,H,J,S) were used in the generation of all stimulus screens. In the *target only* (A) condition only yellow letters appeared, displayed in random order, and randomly placed in the left or right target position. The *target distractor* (B) condition consisted of yellow target letters and blue distractor letters appearing beside one another. Target and distractor letters were randomly placed in the right or left position and were paired with the precondition that distractors were not to be the same as the present, previous, or

following target or distractor. In the *ignored prime* (C) condition yellow target and blue distractor letters were again placed randomly either in the left or right position. In this condition the distractor on pair |N| became the target on pair |N+1|. Each subject completed 6 trials of the 3 conditions for a total of 18 trials. The 18 trials were divided into 6 blocks with each condition appearing once within a block. The order of condition presentation was as follows, BCA,CAB,ABC,BCA,CAB,ABC. The time required to read all yellow letters was recorded by the experimenter using a Timex digital stopwatch. Reading times from the negative priming task can be used to obtain a measure of distraction, by subtracting the *target only* from the *target distractor* condition, and a measure of active inhibition, by subtracting the *target distractor* from the *ignored prime* conditions.

Subjects were seated in front of a 20" color computer monitor and allowed to adjust viewing distance to achieve optimal clarity of the screen. Instructions were read aloud to the subject and three practice trials were completed by the subject. Subjects were instructed to read all yellow letters, reading down the first column and continuing down the second, to ignore blue letters when they appeared in the list, to read each list as quickly and accurately as possible, and to advance through the 18 trials at their own pace. Practice trials consisted of one *target only* trial and two *target distractor* trials. An example of the *ignored prime* condition was not included in the practice trials to avoid any possibility of discovery of the pattern. Each trial began with the subject pressing a key on the keyboard. A 6 second countdown appeared on the screen while a printer printed the letters to appear in the trial for error confirmation. There was approximately a 3 second delay between the end of the printing and the appearance of the list. At the end of the countdown a tone sounded signaling the appearance of the list. At the tone the list appeared where it remained on the screen until the subject pressed a key to begin the next trial. Subjects reading time was recorded from the sounding of the tone to the reading of

the last letter to the nearest 100th second. Responses were also audio tape recorded for scoring of errors.

In the Wisconsin Card Sorting Task (WCST) the subject sorted a series of cards according to three criteria--color, form, and number--with each dimension having four possibilities (Color: red, blue, yellow, green; Form: triangle, circle, cross, star; Number: one to four stimuli). Two measures were included from the WCST. The number of categories achieved, defined as the number of categories correctly sorted, and the number of perseverative errors committed, defined as trials when a subject continued to sort to a category that was no longer correct or continued to sort to a category initially incorrect.

The Cognitive Estimation Task (CET) has been adapted for use with American subjects. For example, references to Britain or England were changed to the United States or America. In addition, references to objects not common in the United States were changed to be more representative of American culture. One example of such a change was the replacement of 'double-decker bus' with 'school bus'. This task consists of a series of estimation questions to which the answers may not be readily apparent to the subject. Subjects were instructed that while they may not know the answers to the questions they should try to make a reasonable estimate. Questions were read aloud to the subject and answers recorded by the experimenter. Scoring of responses was done according to Shallice's original formula and represent the number of extreme responses. For the CET, normative responses were established from answers collected from 30 undergraduate psychology students. To do this, response frequencies for each question were examined and acceptable ranges of responses constructed. These ranges were constructed by dropping the highest and lowest 2 responses given by the undergraduates. For questions asking for categorical responses the 4 responses mentioned least often were dropped. Ranges and the percentage of the normative sample falling within these ranges are reported in the appendix.

The UFOV Visual Attention Analyzer is a computer based touch screen driven visual attention screening device in which the subject was asked to perform three tasks. The first, designed to determine the individual's rate of visual information processing, requires the subject to identify which of two stimuli were presented to central vision. From this task the minimum time, in milliseconds, required by the individual to correctly identify the stimuli was determined. The second task was similar. It required the subject to localize a peripheral target while performing the central task described above. In the third task the peripheral target was embedded in a field of distractors. Scores from these parts of the task provide measures of the ability of the individual to divide attention between two stimuli and the effects of visual clutter on this ability. Scores from the third task were used as a measure of visual selective attention.

The Digit Span Forward Subtest of the WAIS-R was used as measure of memory span. In this task the subject is read series of digits at the rate of one per second. The number of digits contained in a series progressively increases across trials. Upon completion of the series the subject must verbally reproduce the series in order of presentation as accurately as possible. Scores on the task represent the number of digit series correctly reproduced.

The Ammons Quick IQ Test (QT) provided a measure of general verbal intelligence. During the QT the subject is required to indicate either verbally or by pointing which of four pictures best represents the meaning of a word. The relationship between the words and the pictures becomes increasingly complex as the task progresses. The task is discontinued when the subject is incorrect on 6 consecutive words or when a list is exhausted.

The Standard Pseudoisochromatic Plates were used to screen the color vision of each subject using the manual recommended 8 of 10 correct on the screen plates as the cut

for normal color vision. Visual acuity was measured using the Bernell BC/LD10 with a cut score of (20/40) corrected vision for normal acuity.

Table 1 List of Measures Included in Analyses

FAS Number of Words	(# of Words - # of Repetitions and Elaborations)
FAS Repetitions and Elaborations	(# of Repetitions + # of Elaborations)
Stroop Interference	(Color/Word Naming Time - Color Naming Time)
Negative Priming Distraction	(Target Distractor - Target Only)
Negative Priming Inhibition	(Ignored Prime - Target Distractor)
WCST Number of Categories	Total Number of Categories Obtained
WCST Perseverative Errors	Total Number of Perseverative Errors
CET	Number of Extreme Responses
UFOV task 3	Reduction in Visual Selective Attention
Digit Span Forward	Number of Digits Correctly Repeated
Ammons Quick IQ Test	Verbal IQ

Procedures

Upon arrival for testing each subject completed a biographical questionnaire and was asked to read and sign an informed consent form. The subject's visual acuity and color vision were then screened and testing began. All tests were completed in a single sitting with testing time ranging from 1 to 2 hours. Subjects were randomly assigned to one of two test sequences (see appendix). Subjects were given a five minute break for approximately every half hour of testing in hopes of not prematurely exhausting the older subjects. Upon completion of all testing, subjects were debriefed accordingly as to the nature of the study, paid, and released.

Chapter IV
Results

Subject Comparisons

The mean ages for the young, young-old, and old-old groups were 22.9, 65.4, and 74.2 years, respectively. The groups did not differ in their years of education (F (2,57)= 1.91, p<.16, MSe= 6.757) or on the Ammons Quick Test (F (2,57)= .94, p<.40, MSe= 68.06), indicating no differences in general verbal intelligence. The failure to detect differences between the age groups on Digit Span Forward (F (2,57)= 2.27, p<.11, MSe= 4.63), indicates no differences in short term memory capacity (see Table 2).

Table 2 Means and (Standard Deviations) for Age Groups Years of Education, QT, and Digit Span

	Young	Young-Old	Old-Old
Age	22.9 (2.86)	65.4 (2.30)	74.2 (2.90)
Yrs Edc.	15.6 (1.35)	14.1 (2.53)	14.35 (3.47)
QT	106.8 (4.71)	110.2 (9.95)	107.6 (9.11)
Digit Span	9.2 (1.74)	8.5 (2.61)	7.75 (2.02)

Hypothesis 1

The hypothesis of declining frontal lobe function with increasing age was examined through the use of a MANOVA with the six frontal lobe function measures (Stroop , WCST categories, WCST perseverative errors, FAS repetitions and elaborations, FAS words, and CET) entered as dependent measures and age group entered as the independent measure. This analysis is considered superior to the more typical multiple Univariate analyses because of the significant correlations (Bartlett test of sphericity =59.18, p<.001) between the frontal lobe measures (see Table 3).

Table 3 Correlation Matrix for Frontal Lobe Measures

	1	2	3	4	5	6
1 Stroop Interference	1.00					
2 WCST Categories	-.32*	1.00				
3 WCST Perseverative	.42**	-.73**	1.00			
4 FAS Reps & Elabs	.18	.05	.11	1.00		
5 FAS # of Words	-.40**	.18	-.22	.13	1.00	
6 CET	-.14	-.01	.05	-.06	-.02	1.00

1-tailed Significant: * .01 ** .001

All Multivariate tests of between group differences on the frontal lobe measures were significant (all F's > 3.28, p's<.001), indicating a general decline in frontal lobe function with increasing age. Given the significance of the MANOVA, follow-up Univariate analyses were conducted on all frontal lobe measures to aid in understanding which measures contributed to group differences. Four of these analyses (Stroop interference, WCST categories, WCST perseverative errors, and FAS repetitions and elaborations) reached significance (all F's (2,57)> 4.85, p's<.001, see Table 4). Tukey post-hoc procedures revealed differences between young and old-old on each of the measures and

between young and young-old on Stroop interference and FAS repetitions and elaborations (p<.05).

Table 4 Means and (Standard Deviations) for Frontal Lobe Measures

	Young	Young-Old	Old-Old
Stroop Interference	3.91 (2.46)	8.26 (3.75)	10.75 (6.16)
WCST Categories	5.20 (1.36)	4.10 (1.75)	3.65 (1.72)
WCST Per. Errors	4.85 (5.18)	10.25 (10.14)	13.90 (11.19)
FAS Reps and Elabs	1.65 (2.18)	3.70 (2.32)	4.50 (2.70)
FAS # of Words	37.90 (9.58)	34.20 (14.08)	34.80 (10.51)
CET	4.10 (2.15)	3.25 (2.04)	3.60 (1.46)

Stroop Interference- difference in naming time between
Color Screen and
Color/Word Screen
WCST Categories- number of categories achieved
WCST- number of perseverative errors
FAS Reps and Elabs- number of repetitions and elaborations committed
FAS Number of Words- number of valid words given by subject
CET- number of extreme estimates

Hypothesis 2

To examine the hypothesis that frontal lobe function was related to differences in inhibitory function/increased distractability, a frontal lobe composite score was constructed made up of the Stroop interference score, WCST category and perseverative error scores, and FAS repetitions/elaboration's score (see Table 3). The composite was

limited to these measures as they seemed to provide the best index of changes in frontal lobe function resulting from age (i.e., they were the 4 to show significant declines with age). To control for scaling differences among the 4 measures, z-scores were calculated for each measure. Z-scores for the Stroop, WCST perseverative errors, and FAS repetitions/elaboration's were summed together and the WCST categories score was subtracted, (recall that low WCST category scores represent poor performance while high scores on the other 3 measures reflect poor performance). This composite was then divided by 4 to obtain averaged standard scores. The frontal lobe composite was then entered into a stepwise regression analysis as the criterion variable with 3 measures of inhibition/distraction (UFOV task 3, negative priming distraction, and negative priming scores) entered as predictors.

On the first step of the analysis UFOV task 3 entered the equation (*R-squared*= .33, F(1,58)= 28.26, p<.0001, MSe= 3.41), negative priming distraction and negative priming inhibition failed to enter the equation on the next step. Given the significant correlation between Stroop interference and UFOV task 3 scores (r =.50, p<.001) one could argue that the significant *R-squared* observed above was predominately driven by the relationship between the two measures of distraction and that no unique insight into frontal lobe function was being gained. To examine this question a new frontal lobe composite, omitting the Stroop interference score, was constructed and the regression analysis run again. As in the first analysis UFOV task 3 was the only predictor to enter the equation (*R-squared* =.24, F (1,58)= 18.54, p<.001, MSe=3.55). This analysis indicates that differences in distractability continue to share a significant portion of the variance associated with frontal lobe function when the contribution of Stroop interference is removed. To further explore the relationship between distraction and frontal lobe function, separate regression analyses were then conducted using each element of the frontal lobe composite as the criterion variable and the three

inhibition/distraction measures entered as predictors. On each of the four analyses, UFOV task 3 was the only predictor to enter the equation, producing a significant *F-ratio* for each variable (WCST perseverative errors *R-squared*= .08, p< .03; WCST categories *R-squared*= .14, p< .004; FAS repetitions/elaboration's *R-squared*= .16, p< .002; Stroop interference

R-squared= .25, p< .0001). These findings indicate that declines in frontal lobe function with age are related to increases in distractability observed across the adult years. These findings appear to be consistent with the anecdotal suggestion that frontal impaired individuals often seem to suffer from an inability to ignore distracting or irrelevant information.

Hypothesis 3

To investigate the hypothesis that older subjects with high degrees of inhibitory function loss would perform poorly on the measures of frontal lobe function compared to older subjects who had no or limited inhibitory loss, older subjects were grouped according to performance on the negative priming inhibition measure. To accomplish this grouping a median split was performed on negative priming inhibition scores with subjects below the median (n=20) being classified as poor inhibitory function and those scoring above the median being classified as good inhibitory function (n=20). Four Univariate ANOVA's were then performed with Stroop interference, WCST perseverative errors , WCST categories, and FAS repetitions/elaborations entered as dependent measures and inhibition grouping serving as the independent variable. None of the analyses reached significance (all F's (1,38)< 1.00), indicating that when grouped on inhibitory function older subjects did not differ in frontal lobe function.

The findings of the three hypothesis' exploring differences in frontal lobe function across the adult life span suggest that there is a significant decline in frontal lobe function with age. This decline appears to be related to increases in distractability observed with

age given the significance of the regression analyses indicating a significant relationship between UFOV task 3 and the measures of frontal lobe function. Frontal lobe function does not appear to be related to active inhibition of distractors. As older subjects grouped on inhibitory function (i.e., facilitation vs. inhibition) failed to differ on the measures of frontal lobe function.

Hypothesis 4

The hypothesis of increasing distractability with age was examined with two 3(age group) X 2(condition) ANOVA's, with repeated measures on the condition (with vs. without distractors) variables for the Stroop and negative priming distraction. A Univariate ANOVA was used to test the effect of distraction on UFOV task 3.

The first analysis examined the effect of the presence of color names (color screen vs. color/word screen) on color naming times in the Stroop Color/Word Test. The analysis revealed a significant effect of group ($F(2,57) = 25.69$, $p < .001$, $MSe = 26.69$), indicating increasing naming times with age (see Table 5); a significant effect of distraction ($F(1,57) = 181.13$, $p < .001$, $MSe = 9.68$), indicating slowed naming times with the presence of distracting word information; and a significant interaction ($F(2,57) = 12.35$, $p < .001$, $MSe = 9.68$), indicating older subjects were more slowed by the addition of the conflicting word information.

Table 5 Mean Color Naming Time and (Standard Deviations for Stroop Color/Word Test (in seconds)

	Color	Color/Word
Young	9.39 (3.13)	13.31 (4.64)
Yng-Old	11.61 (2.78)	19.87 (3.45)
Old-Old	14.25	25.00

Tukey post-hoc procedures revealed that the detrimental effect of adding color names was significantly greater for the old-old and young-old compared to the young subjects. The two older groups did not differ.

Errors, defined as occasions when the subject named the wrong color (in the color condition) or read the word (in the color/word condition), were submitted to a similar analysis. Errors were infrequent on both the color and the color/word screens (see Table 6). The analysis revealed a non significant effect of age group ($F(2,57)=2.03$, $p<.15$, $MSe=2.01$), indicating that errors did not increase significantly with age; a significant effect of distraction ($F(1,57)=10.10$, $p<.002$, $MSe=1.82$), indicating increased errors when distracting word information was present; and a non significant interaction ($F(2,57)=2.03$ $p<.20$, $MSe=1.82$).

Table 6 Mean Errors and (Standard Deviations) for Stroop Color/Word Test

	Color Screen	Color/Word Screen
Young	0.00 (0.00)	0.15 (0.49)
Yng-Old	0.00 (0.00)	1.00 (2.85)
Old-Old	0.10 (0.43)	1.30 (1.72)

A second measure which permitted an examination of the effects of distraction involved the comparison of letter reading speed with and without distractors in the negative priming task. The analysis revealed a significant effect of age group ($F(2,57)=6.70$, $p<.01$, $MSe=10.68$), demonstrating slower reading speeds for older relative to young subjects; a significant effect of distraction ($F(1,57)=45.38$, $p<.001$, $MSe=.39$),

indicating slower reading speed with the presence of distractors; and a significant interaction ($F(2,57)= 3.85$, $p<.03$, $MSe= .39$), indicating older subjects were more affected by the presence of dictractors than young subjects (see Table 7). Tukey post-hoc procedures performed on the mean distractor effects (target distractor - target only) for the 3 groups suggest that the 2 older groups were equally affected by the presence of the distractor being slowed by approximately one second. In addition, these analyses revealed a significant difference between the young and young-old groups.

Table 7 Mean Letter Reading Time (in seconds) and (Standard Deviations) for Negative Priming Task

	Target Only	Target Distract.	Ignored Prime
Young	10.63 (1.93)	10.96 (2.08)	11.33 (2.16)
Yng-Old	12.66 (2.71)	13.75 (3.04)	14.20 (3.59)
Old-Old	12.56 (2.17)	13.45 (1.98)	13.33 (2.18)

For the negative priming task errors were defined as occasions when the subject misread a letter, or read the to-be-ignored letter. Errors were infrequent, equaling less than 1% of responses for all groups and the two ANOVA's revealed no significant effects of age group or condition.

The final analysis related to hypothesis 4 examined the effect of distractors on the ability of the subject to localize peripheral visual targets, this was done by comparing UFOV Task 3 scores for the three age groups. A significant effect of age was found ($F(2,57)= 81.25$, $p<.0001$, $MSe= 26.90$), indicating that the addition of distractors impaired the older subject's ability to localize the peripheral target (see Table 8).

Tukey post-hoc procedures revealed significant differences between all three age groups ($p<.05$), indicating that the effect of distractors increased across the three age groups.

Table 8 Mean and UFOV Task 3 Percent Reduction and (Standard Deviations)

Young	Young-Old	Old-Old
4.13 (3.83)	18.75 (5.53)	24.38 (5.95)

The findings related to hypothesis 4 suggest there is a significant increases in distractability with age. The older subjects were significantly more impaired by distractors than the young subjects on each of the three distraction measures. The detrimental effect of distractors on older subjects is seen when both verbal and spatial materials are used. This susceptibility to distraction could result from a general decline in the ability of some older subjects to efficiently select task relevant information. This suggestion is also supported by the significant correlations between the distraction measures.

Table 9 Correlation Matrix for Measures of Inhibition and Distraction

	1	2	3	4
1 Stroop Interference	1.00			
2 Negative Priming Distraction	.25*	1.00		
3 UFOV Task 3	.50**	-.29*	1.00	
4 Negative Priming Inhibition	-.07	-.26*	-.03	1.00

1-tailed Significant: *.05 **.001

Hypothesis 5

To examine the hypothesis related to changes in inhibitory function with age, a measure of active inhibition was obtained by comparing reading speed on the ignored prime and target distractor conditions of the negative priming task. This analysis revealed an effect of age group ($F(2,57)= 6.90$, $p<.002$, $MSe= 12.94$), indicating, once again, slower reading speeds for the older subjects relative to younger subjects; of suppression ($F(1,57)= 4.71$, $p<.05$, $MSe= .35$), indicating slower reading speeds for the ignored prime condition, and therefore evidence of active inhibition; the interaction, however, was only marginally significant ($F(1,57)= 4.71$, $p<.07$, $MSe= .35$), indicating that negative priming was preserved in at least some of the older subjects (see Table 7). This finding is interesting, considering past research has failed to find evidence of negative priming in older subjects (Hasher et al., 1991; Tipper, 1991).

In order to gain a clearer understanding of the unexpected finding of preserved inhibitory function in some older adults in the above analysis the negative priming effects (ignored prime - target distractor) for subjects within each age group were examined. In the young group this analysis revealed 18 subjects who demonstrated suppression(scores were positive) and 2 subjects who had weak facilitory effects (scores were negative), indicating that most of the young subjects showed negative priming. When this analysis was performed on the young-old and old-old groups, both groups contained 10 subjects who demonstrated inhibitory effects and 10 subjects who demonstrated facilitory effects (see Table 10). To further explore this finding single sample t-tests were conducted for inhibitors and facilitators within each of the older groups to determine if these effects were significantly different from zero. In the young-old group the suppression effect of 1.179 seconds was significant ($t(9)= 3.59$, $p< .05$), and the facilitory effect of .266 seconds was also significant ($t(9)= 3.35$, $p< .05$). In the old-old group the suppression effect of .557 seconds ($t(9)= 2.93$, $p< .05$) and the facilitation effect of .795 seconds

(t (9)=3.89, p< .05), were both significant. This analysis indicates that while some older subjects have experienced declines in inhibitory mechanisms, others appear to have relatively intact inhibitory mechanisms through the seventh decade of life.

Table 10 Facilitation and Inhibition Effects (in seconds) for Age Groups Means, (Standard Deviations), and Cell Counts

	Inhib.	Facil.
Young	0.412 (0.388) n= 18	0.055 (0.063) n= 2
Yng-Old	1.179 (1.038) n= 10	0.266 (0.251) n=10
Old-Old	0.557 (0.602) n= 10	0.795 (0.646) n= 10

Chapter V

Discussion

Frontal Lobe Function

In the present study two hypotheses related to frontal lobe function were examined. First, the prediction was made that there would be a general decline in frontal lobe function with increasing age; and, secondly, that this decline would be related to an increase in the susceptibility to distraction often observed in older individuals. The first hypothesis was well supported with significant age group differences being revealed in four of the six measures of frontal lobe function used in the study. Correlations between age and the number of categories achieved and the number of perseverative errors produced in the present study are very similar to those reported by Shoqeirat et al. (1990; number of categories, r =.39 and r =.36; number of perseverative errors, r =-.39 and r =-.49). Declines in word fluency were reflected by an increase in the number of repetitions and elaborations suggesting older subjects experienced difficulty in monitoring ongoing responses and inhibiting past responses. The number of words generated on the FAS did not differ for the three age groups. Similar findings are reported in a study by Purlmuter et al. (1987), where older adults produced significantly more repetitions and elaborations while word production was unaffected by increasing age. Older subjects also experienced greater slowing due to conflicting information on the Stroop Color/Word Test (see discussion above). The Cognitive Estimation Task was the other measure of frontal lobe function not impacted by the effects of increasing age. One possible explanation for this finding rests in the observation that most subjects, including those in the normative sample, seemed to be generally poor estimators. These findings of a general

decline in frontal lobe function with increasing age support a growing body of literature advocating this position (Craik et al., 1990; Whelihan & Lesher, 1985; Ardila & Rosselli, 1989). Changes in frontal lobe function cannot be attributed to a general decline in cognitive function with age as the present study revealed that our old and young subjects did not differ either in their general verbal intelligence or their short term memory capacity.

The second hypothesis predicting a significant relationship between frontal lobe function and susceptibility to distraction was also well supported. In a series of regression analyses using both composite and single measures of frontal lobe function, susceptibility to distraction, as measured by UFOV task 3 performance, was found to be significantly related to frontal lobe function. These findings suggest that an inability to efficiently select task relevant information may play a crucial role in deficits frequently observed on measures of frontal lobe function in older adults and clinical populations (see Kolb & Whishaw, 1983). This relationship seems especially relevant to a theoretical model by Norman and Shallice (1980, also see, Shallice, 1982) which proposes that the impairment of a "supervisory attentional system," responsible for modulating behavior when numerous alternatives are available for selection, is primarily responsible for frontal lobe related deficits. The impairment of this "supervisory attentional system" could result in poor selectivity, sustained activation of irrelevant information (i.e., poor inhibition), and an inability to respond efficiently to novel task demands. The decline of such a supervisory mechanism with age provides a reasonable explanation for many of the cognitive related problems older individuals often face. Problems such as source amnesia, text processing, and selective attention (Craik et al. 1990; Shaw et al. 1992; Madden, 1983), all involve the ability to efficiently select task relevant information and effectively ignore or inhibit distracting or irrelevant information. The significant relationship between frontal lobe function and susceptibility to distraction also provides validation for the position taken by

Dempster (1991) suggesting "that individual and group differences in the capacity for inhibition (i.e., *resistance to interference*) are manifestations of the efficiency of the frontal cortex of the brain"(p. 157).

Inhibition and Distraction

The results of the present study are generally consistent with the theoretical position suggesting a decline in the efficient functioning of inhibitory mechanisms with age. This decline can be seen in both the increased susceptibility to distracting information in the form of visual clutter, competing color/word information, and paired letters, and an absence of active inhibition of related distractors in some older subjects. In order to facilitate comparisons between findings in the present study with those reported in other studies a percentage of effect strategy was adopted (see Tipper, Bourque, Anderson, & Brehaut, 1989). The percentage of effect is determined by dividing the experimental effect value (experimental - control conditions) by the reading or naming time for the control condition. This approach allows comparisons of findings based on pooled and single response tasks or pooled response tasks requiring different numbers of responses to be made.

The detrimental effect of the presence of distracting information, whether in the form of visual clutter, competing color names or paired letters, was far greater for both the young-old and old-old groups than for the young group on the three measures of distractibility. The presence of a distractor letter in the negative priming task resulted in the reading times of the young-old and old-old groups being slowed 2 to 3 times more than that of the young group in the study (percentage of slowing, young 3%, young-old 7%, old-old 9%). Similar findings are reported by McDowd and Oseas-Kreger (1991) where old subjects were twice as impaired as young subjects in a task requiring pooled responses and Tipper (1991) who reports that older subjects were 5 times more impaired than young subjects by the presence of a distractor in a single response task. Results from

the Stroop Color/Word Test suggest similar degrees of impairment for older subjects. In the present study young-old and old-old groups color naming times were slowed (78% and 87%, respectively) by the addition of competing color/word information almost twice as much as young subjects (44%). Consistent with results reported by Comalli et al. (1962) where old subject's color naming times were slowed nearly twice as much (141%) as young subjects (79%) with competing information in a Stroop task requiring 100 responses. On UFOV task 3 the young-old and old-old groups were 3 to 4 times more impaired by the presence of distractors than the young group (see Table 8). This increased susceptibility to visual clutter can also be seen in the fact that all older subjects scored above the most impaired of the young subjects on UFOV task 3. The findings reported above from this and other studies indicate a significant increase in susceptibility to distraction for many older individuals suggested by their increased error rates when asked to localize a visual target embedded in a field of clutter and their increased response time when distractors are present in a reading and naming task.

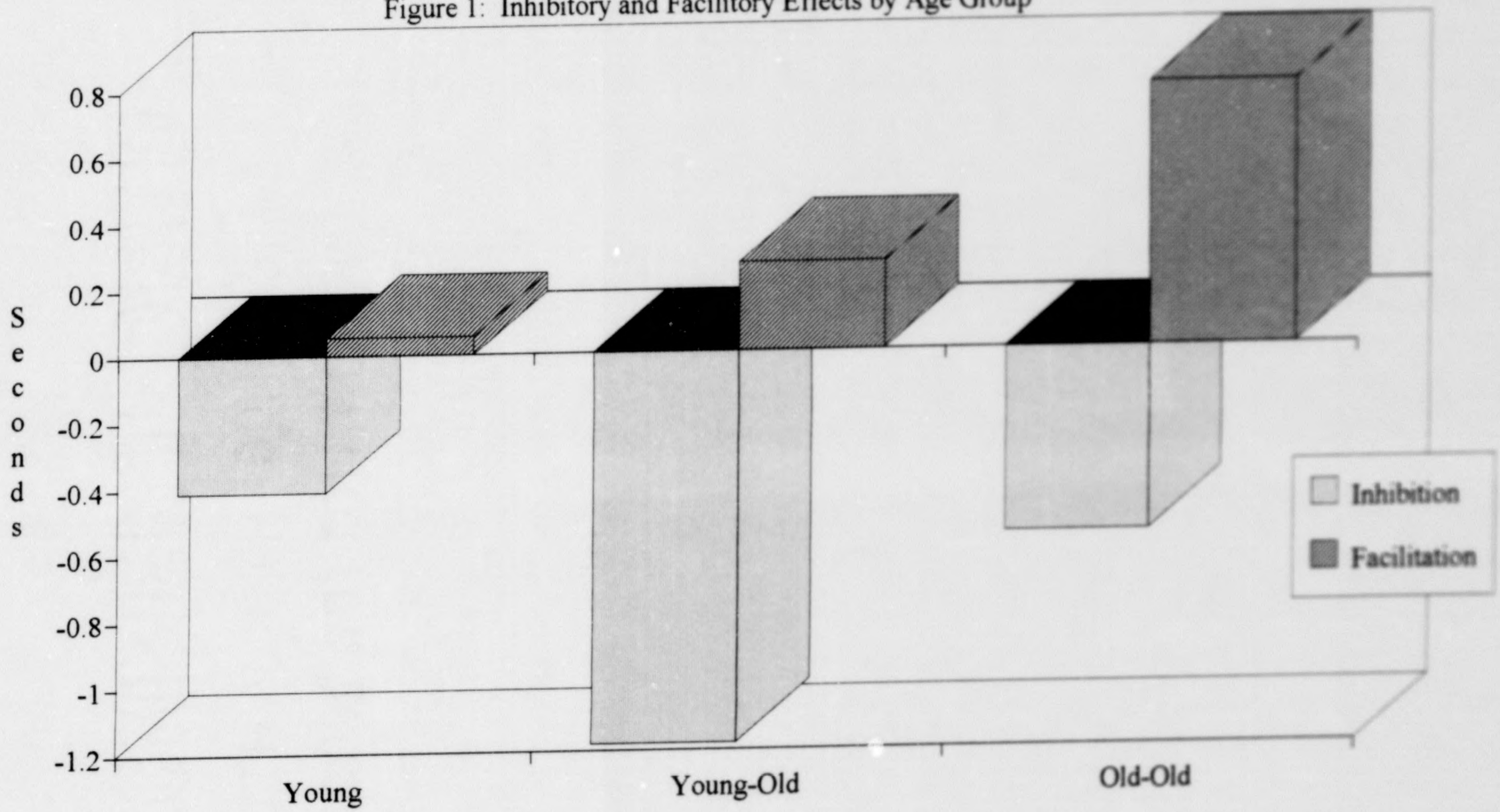
A measure of active inhibition was obtained in the present study through the use of the negative priming paradigm. On this task the reading times of the young subjects (mean age 22.9) were slowed about 3% by the presence of a related distractor letter. This finding is consistent with effects reported in other studies which typically range from 2.5% to 5% (Tipper & Driver, 1988; Tipper, 1985). Our old-old (mean age 74.2) showed a slight facilitation effect of about 1%, consistent with results reported by Tipper (1991), suggesting this group actually benefited from the presence of the related distractors. Unlike the old-old group, the young-old group (mean age 65.4) demonstrated a negative priming effect of 3%, equal in magnitude to that found in the young subjects in this study as well as other studies. This finding was certainly unexpected given past research which has failed to find evidence of negative priming in older subjects. One possible explanation for the discrepancy between the present findings and those reported in earlier studies could

rest in the grouping of older subjects. Past research has included all older subjects in a single group (age ranges 57-77, Tipper, 1991; 62-75, Hasher et al. 1991). This type of grouping could have resulted in poor performing old-old subjects masking a small but significant effect of suppression in young-old subjects. A reasonable position given that in the present study when all older subjects were collapsed into a single group, the negative priming effect was insignificant (mean effect .17 seconds; $t(39)=1.05$, $p<.30$).

In an attempt to gain a clearer understanding of changes in active inhibition with age, facilitation and inhibition effects were examined for each of the three age groups (see Figure 1). This analysis revealed that 18 of the 20 young subjects demonstrated a suppression effect for the related distractor. Similar findings are reported in a study using only young adults where 100% of the subjects demonstrated negative priming (Tipper, Weaver, Kirkpatrick, & Lewis, 1991). In both the young-old and old-old groups, ten subjects demonstrated inhibition and ten subjects demonstrated facilitation with each of these effects being significantly different from zero. This analysis suggests that while some older individuals do seem to have experienced declines in their ability to actively inhibit a distracting stimulus, there are a fair number, in this case 50%, of older adults who possess relatively intact active inhibitory mechanisms into their seventh decade of life. A number of questions arise from the present findings that need to be addressed in future research: Can this finding of sustained active inhibitory function in some older adults be replicated in a single response negative priming task? At what age do individuals begin to experience declines in active inhibitory mechanisms? In what ways do older individuals with intact inhibitory mechanisms differ from those who experience decline in inhibitory efficiency?

From the theoretical model proposed by Hasher and Zacks (1988) one would predict an inverse relationship between active inhibition and susceptibility to distraction.

Figure 1: Inhibitory and Facilitory Effects by Age Group



suggesting that those individuals with the most efficient inhibitory mechanisms should be least affected by distractors. Is it the case that individuals with inefficient or absent inhibitory mechanisms in turn suffer from greater degrees of distractibility or are the two processes relatively independent? One Study using the Cognitive Failures Questionnaire (see Broadbent, Cooper, Fitzgerald, & Parks, 1982) as the measure of distractibility and a negative priming task to measure of active inhibition, indicated just such a relationship (Tipper & Baylis, 1987). In this study a significant interaction between CFQ and negative priming was reported, leading the researchers to suggest than an "enhanced ability to select a target from a distractor........may in part be due to increased degree of inhibition of the internal representation of distractor objects" (Tipper & Baylis, 1987, p. 673). No correlation between negative priming and CFQ scores was reported however, making it difficult to establish the nature or magnitude of this relationship. Correlations between CFQ scores and measures indicating the cost of unrelated distractors to response latency were reported, however, suggesting to the critical reader that the relationship between CFQ and active inhibition may have been tenuous. A second study by Tipper et al. (1991) failed to discover an inverse relationship between active inhibition and distraction in a spatial negative priming task. The same study reported that when a mask followed stimulus presentation a significant disruption of negative priming was observed, while the interference resulting from a distractor was unaffected by the presentation of the mask. A possible explanation for the disrupting effect of the mask can be found in a study by Posner and Cohen (1984), who found that inhibition was relatively slow to develop in an inhibition of return task. Findings from the present study support the later of these two positions, since active inhibition (as measured by negative priming inhibition) failed to correlate significantly with either Stroop interference or UFOV task 3 (both robust measures of distraction) and only marginally with the negative priming distraction measure (see Table 9). The latter relation may be due to task similarities. In

addition when subjects were grouped according to inhibition/facilitation effects and Univariate ANOVA's conducted with UFOV task 3 and Stroop distraction entered as dependent measures, both analyses failed to reach significance (F's < 1). These findings suggest that "the efficiency of selection is not solely determined by inhibitory mechanisms" (Tipper et al. 1991,
p. 518), as measured in the negative priming paradigm.

One possible explanation for the lack of relationship between distraction and active inhibition comes from the observation that the inhibition attached to the internal representation of an ignored stimulus, in the negative priming paradigm, would develop after the stimulus had been rejected for selection to avoid resampling in a manner similar to that reported in "inhibition of return" research. The failure to find a reliable relationship between distraction and active inhibition in this study suggests two alternatives. First, the proposed importance of inhibitory mechanisms in understanding susceptibility to distraction has been overstated. A second alternative is that negative priming does not represent an efficient means of measuring active inhibition as it relates to increased susceptibility to distraction observed in many older adults. To accept the first of these two alternatives would be to turn a blind eye to a growing body of research and theoretical speculation indicating inhibitory mechanisms play a crucial role in the efficient performance of task requiring selection and active inhibition (Dempster, 1991; Tipper & Baylis, 1987; Connelly, Hasher, & Zacks, 1991). Acceptance of the second alternative would suggest the need to develop new measures of active inhibition which are more robust and reliable and which better reflect possible inhibitory mechanisms active during stimulus selection.

In summary, the findings of the present study compliment a growing body of research indicating that increased susceptibility to distraction can be a problem for many older individuals. This increased distractibility would appear to be a general rather than a

specific impairment given that it was found when both verbal and spatial distractors were employed. Furthermore, the increased distractibility observed in many older individuals in the present study does not seem to have resulted from the decline of some active inhibitory mechanisms, since no significant relationship was found to exist between distraction and inhibition. This is not to suggest that other means of assessing active inhibition would not reveal such a relationship. Regarding declining inhibitory function in later life, the present findings indicate that substantial individual differences may exist between older individuals, with a number of these individuals possessing intact inhibitory mechanisms as efficient as many of their younger counterparts. The findings related to decreased frontal lobe function in older individuals both supports and extends previous work, by suggesting a general decline in frontal lobe function with increasing age and by providing evidence of a significant relationship between frontal lobe function and susceptibility to distraction. In addition to providing a number of interesting findings, the current study also raises several questions which future research could address. To mention only a few, Can the finding of intact inhibitory mechanisms be replicated in a single response negative priming paradigm? What possible differences exist between individuals with and without intact inhibitory mechanisms? And finally, Could the relationship between frontal lobe function and susceptibility to distraction be replicated using physiological measures of function such as MRI and PET techniques.

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Appendix

Scoring Criteria for Cognitive Estimation Task

Testing Sequence for Subjects

Test Sequence for Aging and Inhibition Study

Form A	**Form B**
First Hour	***First Hour***
______ UFOV	______ QT
______ FAS	______ WCST
______ Negative Priming	______ CET
______ Stroop	______ DSF
Second Hour	***Second Hour***
______ QT	______ UFOV
______ WCST	______ FAS
______ DSF	______ Stroop
______ CET	______ Negative Priming

Scoring Criteria for Cognitive

Estimation Task

Q 1. On average how many TV shows are there on any one TV channel between 6:00 and 11:00 PM?

Range: 7 < x > 10 True: 6.12 % of Norm Sample (74)

Q 2. What is the height of the tallest building in the united states?

Range: 400 < x >4000ft True: 1454 % of Norm Sample (71)

Q 3. How fast do race horses gallop?

Range: 20 < x >50mph True: 30-35 % of Norm Sample (75)

Q 4. What is the highest paid job or occupation in the United States today?

Range: Doctor, CEO, Entertainer, President, Stock Broker % (63)

Q 5. What is the age of the oldest person in the United States today?

Range: 102 < x >114 True: 110 % of Norm Sample (83)

Q 6. What is the length of the average man's spine?

Range: 20 < x >36" % of Norm Sample (79)

Q 7. How many slices are in a sliced loaf?

Range: 16 < x > 38 True: 20 % of Norm Sample (75)

Q 8. What is the largest fish in the world?

Range: Shark, Whale, Tuna True: Shark % of Norm Sample (75)

Q 9. How tall is the average American woman?

Range: 5'4" < x >5'6" True: 5'4" % of Norm Sample (67)

Q 10. How heavy is a full half gallon of milk?

Range: 2 < x > 5 lbs True: 4 lbs % of Norm Sample (58)

Q 11. How long is the average tie?

Range: 15 < x >42" True: 58" % of Norm Sample (75)

Q 12. What is the largest object normally found in a house?

Range: Bed, Couch, Refrigerator % of Norm Sample (71)

Q 13. What is the width of a school bus?

Range: 6 < x > 10' True: 8' % of Norm Sample (67)

Q 14. What is the length of a dollar bill?

Range: 5 < x >7" True: 6.5" % of Norm Sample (88)

Q 15. What is the distance between New York and Paris?

Range: 900 < x > 20,000 mls % of Norm Sample (80)